FIG. 1

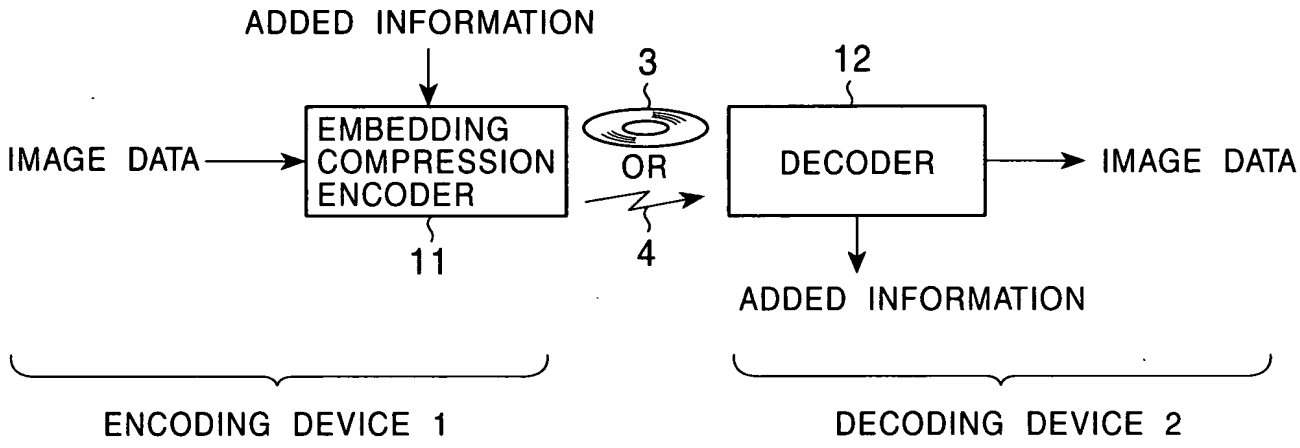
ADDED INFORMATION
3
12
IMAGE DATA
EMBEDDING
COMPRESSION
ENCODER
OR
DECODER
IMAGE DATA
11
4
ADDED INFORMATION
ENCODING DEVICE 1
DECODING DEVICE 2

FIG. 2

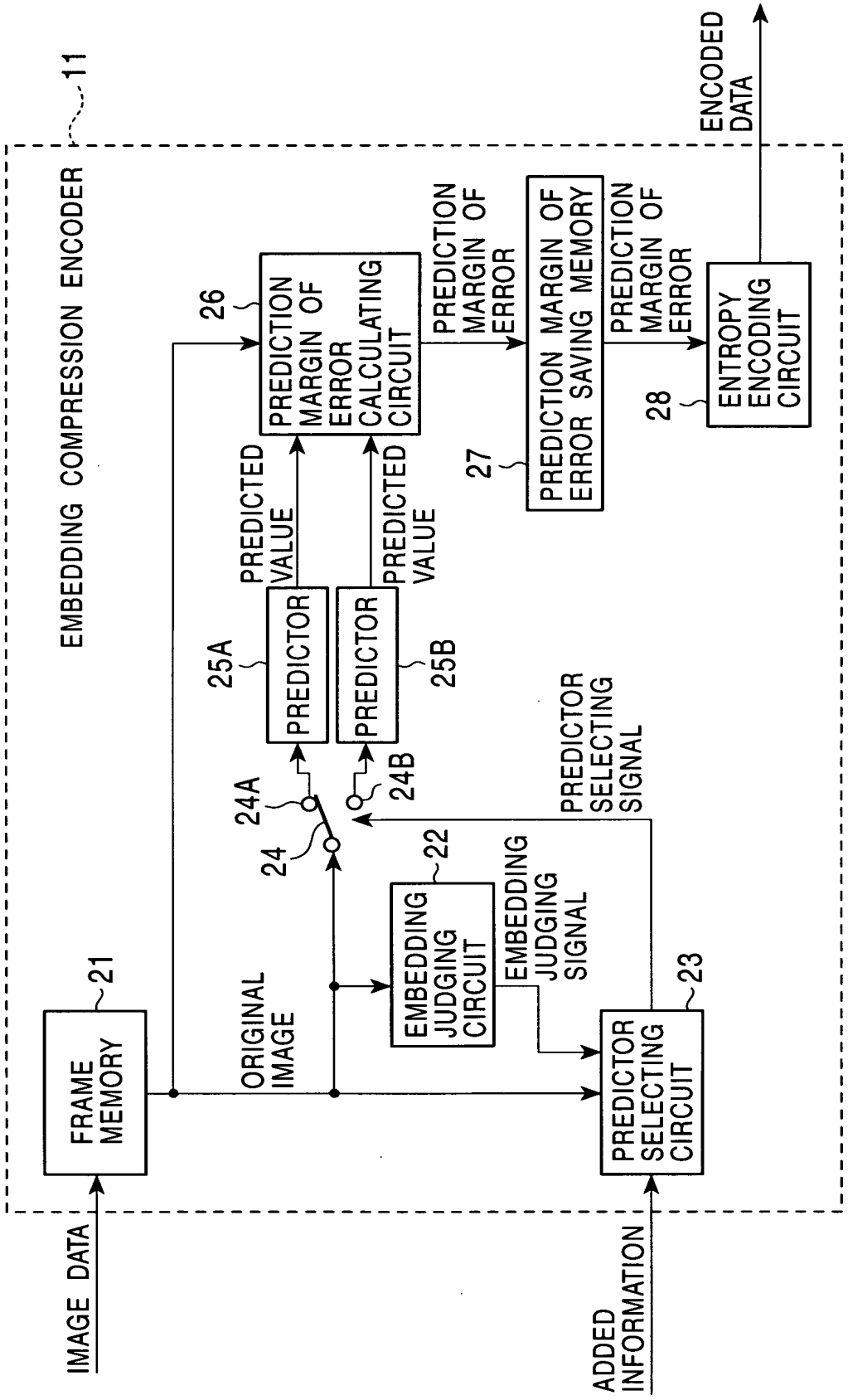
EMBEDDING COMPRESSION ENCODER
11
IMAGE DATA
FRAME MEMORY
21
ORIGINAL IMAGE
ADDED INFORMATION
PREDICTOR SELECTING CIRCUIT
23
EMBEDDING JUDGING CIRCUIT
22
EMBEDDING JUDGING SIGNAL
PREDICTOR SELECTING SIGNAL
24
24A
24B
25A
PREDICTOR
25B
PREDICTOR
PREDICTED VALUE
PREDICTED VALUE
26
PREDICTION MARGIN OF ERROR CALCULATING CIRCUIT
PREDICTION MARGIN OF ERROR
27
PREDICTION MARGIN OF ERROR SAVING MEMORY
PREDICTION MARGIN OF ERROR
28
ENTROPY ENCODING CIRCUIT
ENCODED DATA

FIG. 3

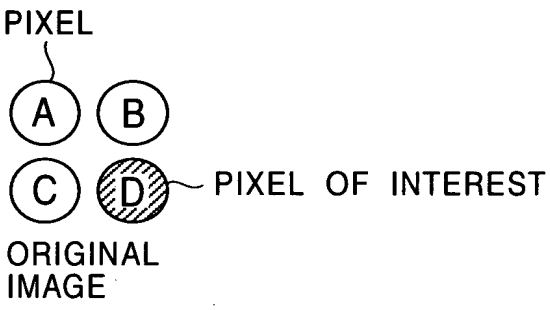


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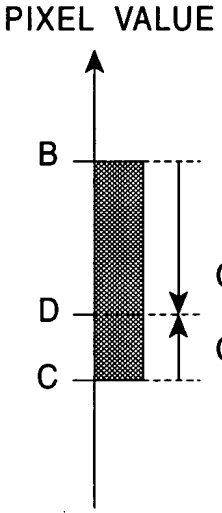
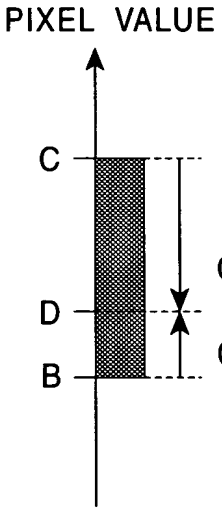
FIG. 4A




| | PREDICTED VALUE | PREDICTION MARGIN OF ERROR |
|---|---|---|
| CASE OF EMBEDDING 0 | B | D−B |
| CASE OF EMBEDDING 1 | C | D−C |

FIG. 4B




| | PREDICTED VALUE | PREDICTION MARGIN OF ERROR |
|---|---|---|
| CASE OF EMBEDDING 0 | B | D−B |
| CASE OF EMBEDDING 1 | C | D−C |

FIG. 5A

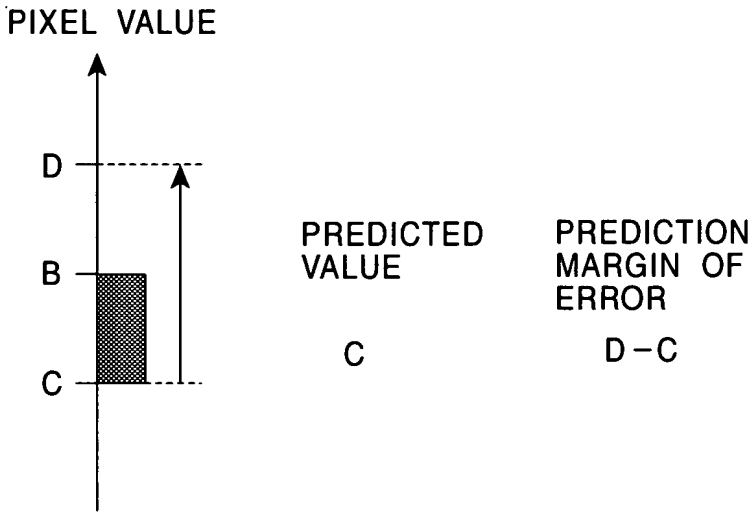

PIXEL VALUE
D
B
C
PREDICTED VALUE
C
PREDICTION MARGIN OF ERROR
D-C

FIG. 5B

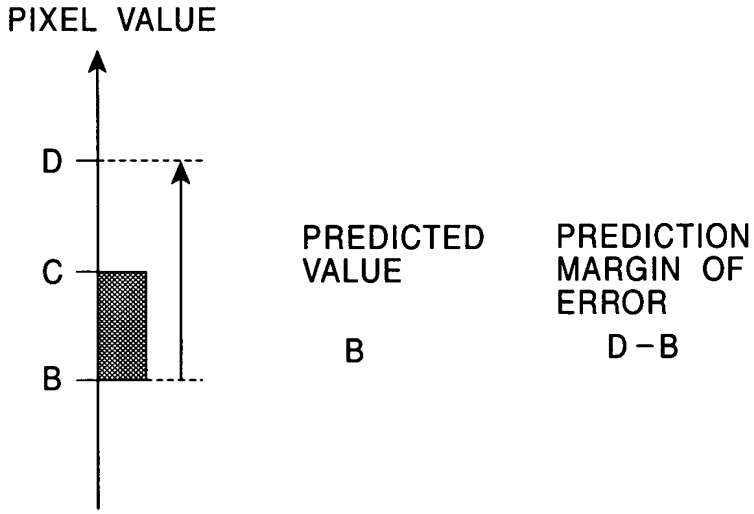

PIXEL VALUE
D
C
B
PREDICTED VALUE
B
PREDICTION MARGIN OF ERROR
D-B

FIG. 6

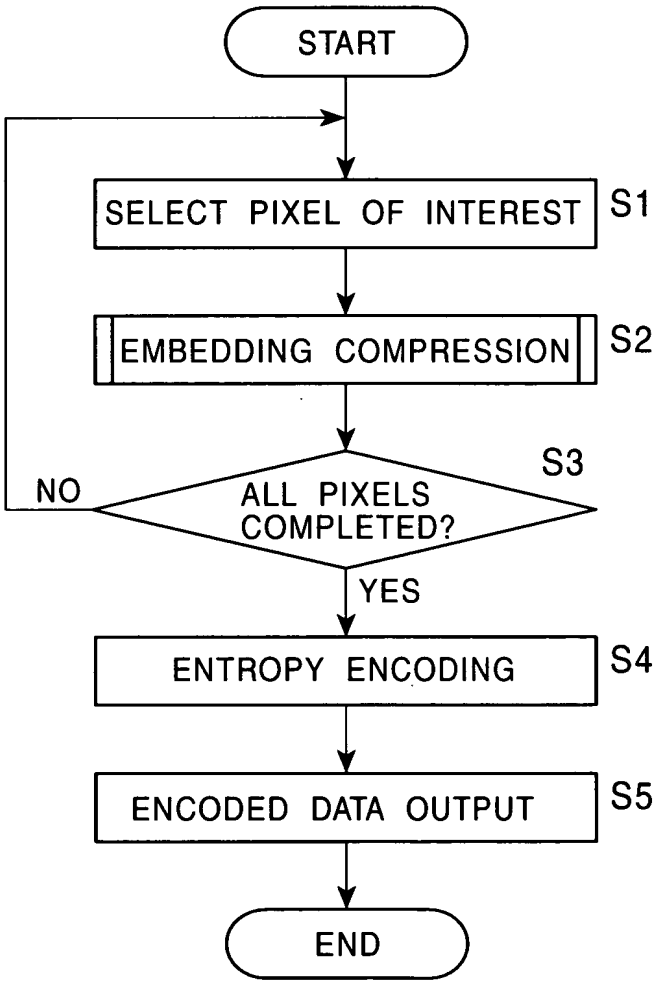

START
SELECT PIXEL OF INTEREST
S1
EMBEDDING COMPRESSION
S2
S3
NO
ALL PIXELS COMPLETED?
YES
ENTROPY ENCODING
S4
ENCODED DATA OUTPUT
S5
END

FIG. 7

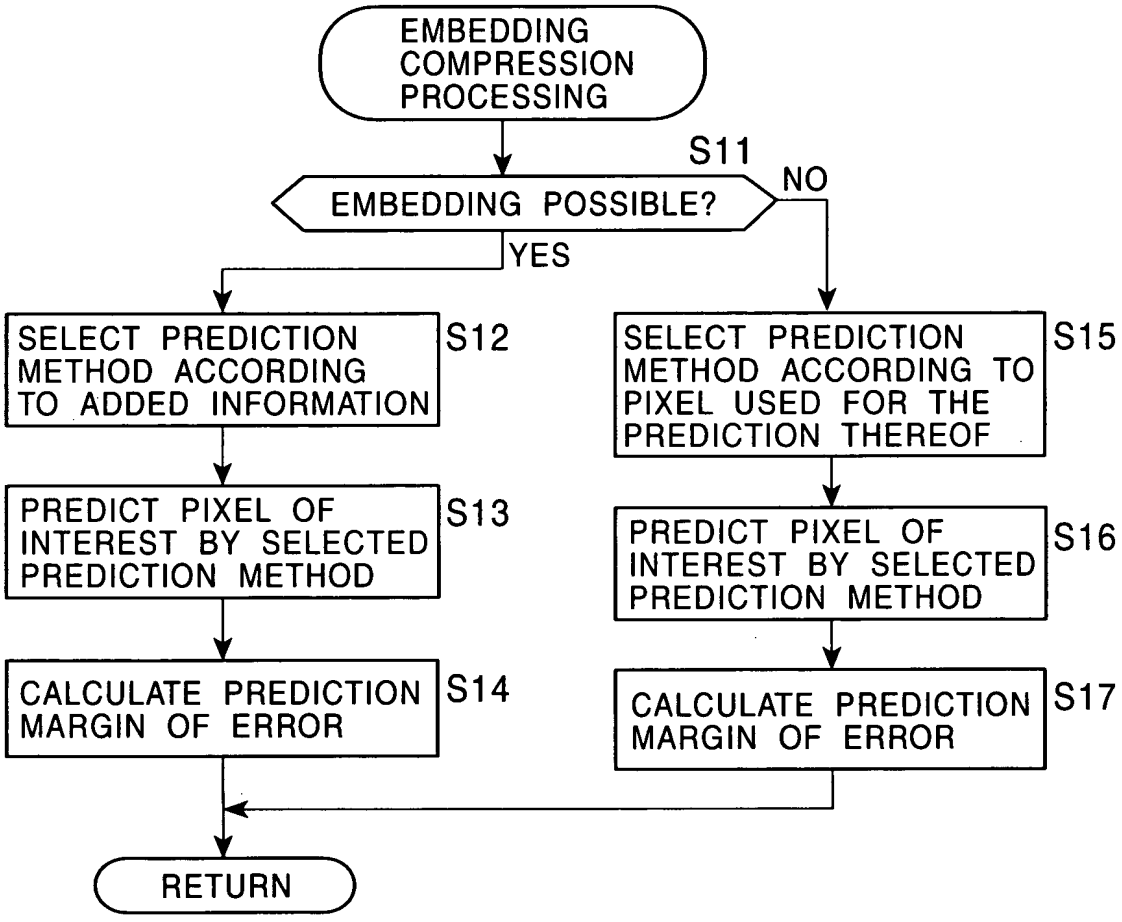

EMBEDDING COMPRESSION PROCESSING
S11
EMBEDDING POSSIBLE?
NO
YES
SELECT PREDICTION METHOD ACCORDING TO ADDED INFORMATION
S12
PREDICT PIXEL OF INTEREST BY SELECTED PREDICTION METHOD
S13
CALCULATE PREDICTION MARGIN OF ERROR
S14
SELECT PREDICTION METHOD ACCORDING TO PIXEL USED FOR THE PREDICTION THEREOF
S15
PREDICT PIXEL OF INTEREST BY SELECTED PREDICTION METHOD
S16
CALCULATE PREDICTION MARGIN OF ERROR
S17
RETURN

FIG. 8

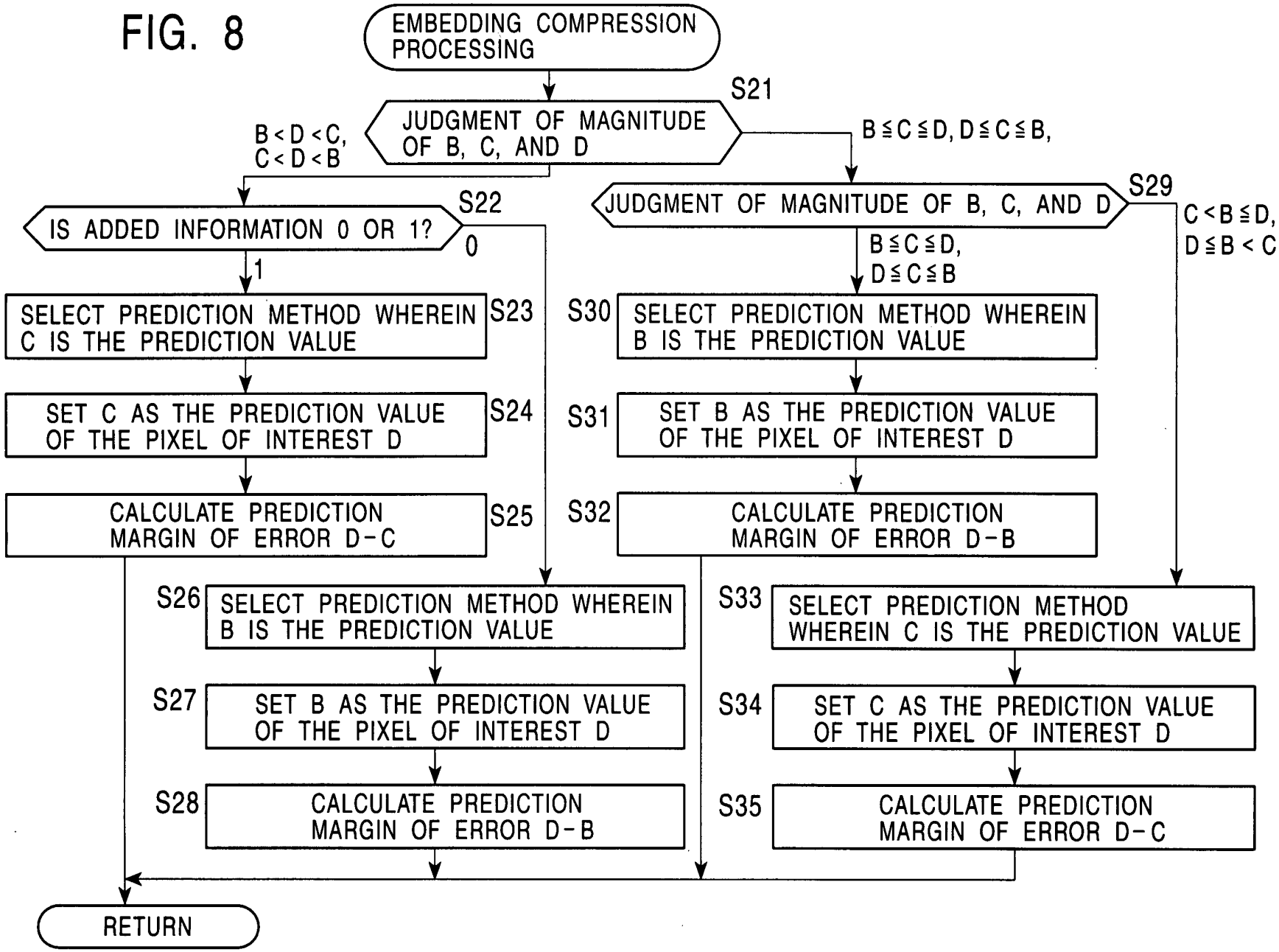

EMBEDDING COMPRESSION PROCESSING
S21
JUDGMENT OF MAGNITUDE OF B, C, AND D
B < D < C, C < D < B
B ≦ C ≦ D, D ≦ C ≦ B,
S22
IS ADDED INFORMATION 0 OR 1?
0
1
S23
SELECT PREDICTION METHOD WHEREIN C IS THE PREDICTION VALUE
S24
SET C AS THE PREDICTION VALUE OF THE PIXEL OF INTEREST D
S25
CALCULATE PREDICTION MARGIN OF ERROR D-C
S26
SELECT PREDICTION METHOD WHEREIN B IS THE PREDICTION VALUE
S27
SET B AS THE PREDICTION VALUE OF THE PIXEL OF INTEREST D
S28
CALCULATE PREDICTION MARGIN OF ERROR D-B
S29
JUDGMENT OF MAGNITUDE OF B, C, AND D
B ≦ C ≦ D, D ≦ C ≦ B
C < B ≦ D, D ≦ B < C
S30
SELECT PREDICTION METHOD WHEREIN B IS THE PREDICTION VALUE
S31
SET B AS THE PREDICTION VALUE OF THE PIXEL OF INTEREST D
S32
CALCULATE PREDICTION MARGIN OF ERROR D-B
S33
SELECT PREDICTION METHOD WHEREIN C IS THE PREDICTION VALUE
S34
SET C AS THE PREDICTION VALUE OF THE PIXEL OF INTEREST D
S35
CALCULATE PREDICTION MARGIN OF ERROR D-C
RETURN

FIG. 9

| RELATION OF B, C, AND D | | EMBEDDING JUDGMENT | ADDED INFORMATION | PREDICTION VALUE | PREDICTION MARGIN OF ERROR |
|---|---|---|---|---|---|
| B ≠ C | B < D < C OR C < D < B | YES | 0 | B | D − B |
| | | | 1 | C | D − C |
| | B < C ≦ D OR D ≦ C < B | NO | —— | B | D − B |
| | C < B ≦ D OR D ≦ B < C | NO | —— | C | D − C |
| B = C | —— | NO | —— | B | D − B |

# FIG. 10

| RELATION OF A, B, C, AND D | | EMBEDDING JUDGMENT | ADDED INFORMATION | PREDICTION VALUE | PREDICTION MARGIN OF ERROR |
|---|---|---|---|---|---|
| B ≠ C | B < D < C OR C < D < B | YES | 0 | B | D − B |
| | | | 1 | C | D − C |
| | B < C ≦ D OR D ≦ C < B | NO | —— | B | D − B |
| | C < B ≦ D OR D ≦ B < C | NO | —— | C | D − C |
| A ≠ B = C | A < D < B OR B < D < A | YES | 0 | A | D − A |
| | | | 1 | B | D − B |
| | A < B ≦ D OR D ≦ B < A | NO | —— | A | D − A |
| | B < A ≦ D OR D ≦ A < D | NO | —— | B | D − B |
| A = B = C | —— | NO | —— | A | D − A |

FIG. 11

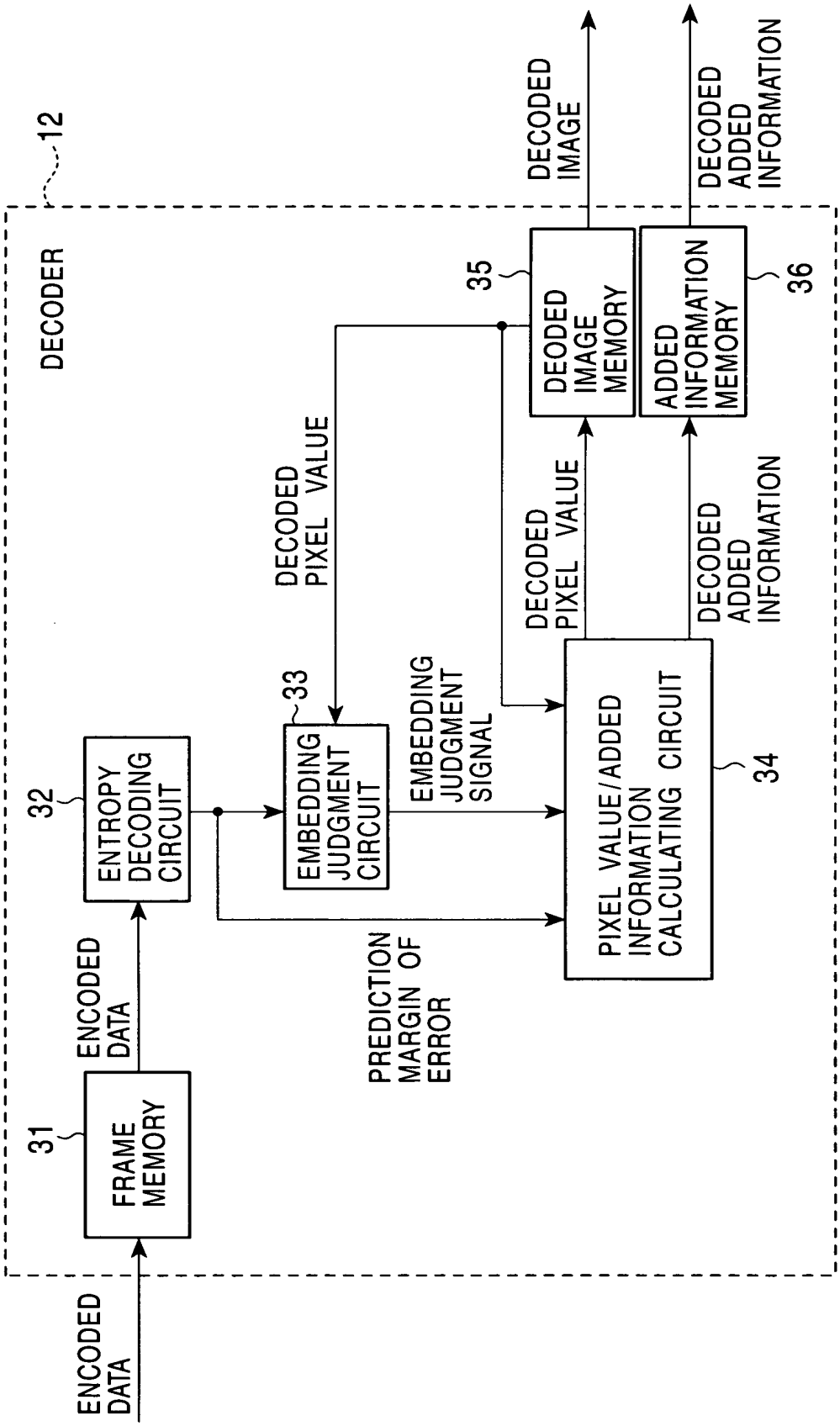
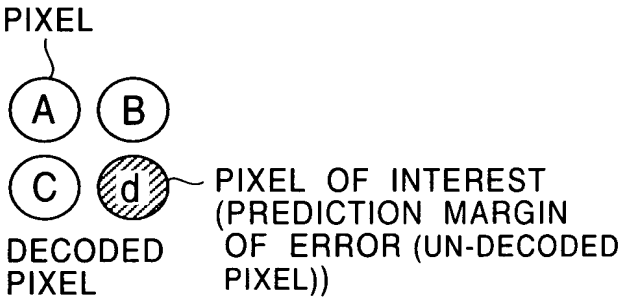
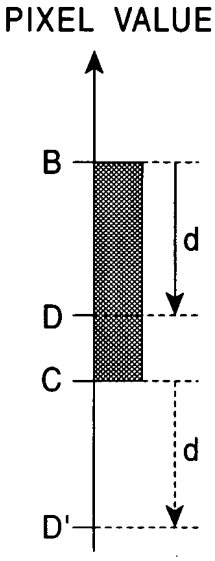

DECODER
12
ENCODED DATA
31
FRAME MEMORY
ENCODED DATA
32
ENTROPY DECODING CIRCUIT
33
EMBEDDING JUDGMENT CIRCUIT
EMBEDDING JUDGMENT SIGNAL
DECODED PIXEL VALUE
PREDICTION MARGIN OF ERROR
PIXEL VALUE/ADDED INFORMATION CALCULATING CIRCUIT
34
DECODED PIXEL VALUE
DECODED ADDED INFORMATION
35
DEODED IMAGE MEMORY
ADDED INFORMATION MEMORY
36
DECODED IMAGE
DECODED ADDED INFORMATION

FIG. 12



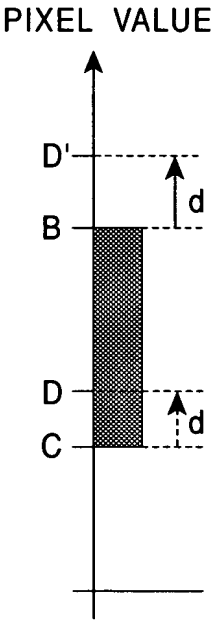

0 0 2 2 4 2 0 9 1 : 0 4 0 2 0 4

FIG. 13A



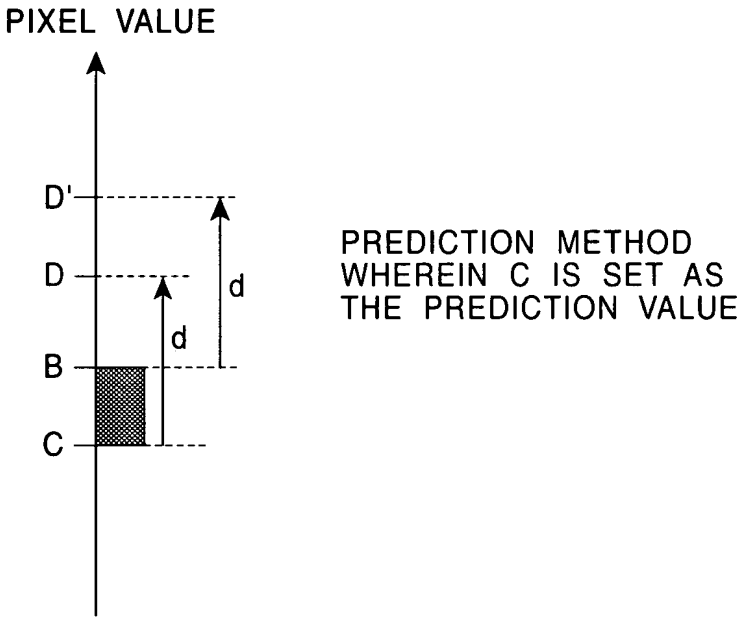

PREDICTION METHOD WHEREIN B IS SET AS THE PREDICTION VALUE → 0 IS EMBEDDED

FIG. 13B




PREDICTION METHOD WHEREIN C IS SET AS THE PREDICTION VALUE → 1 IS EMBEDDED

FIG. 14




0,9,0,4,5,0,9,4 : 0,4,0,2,0,4

FIG. 15

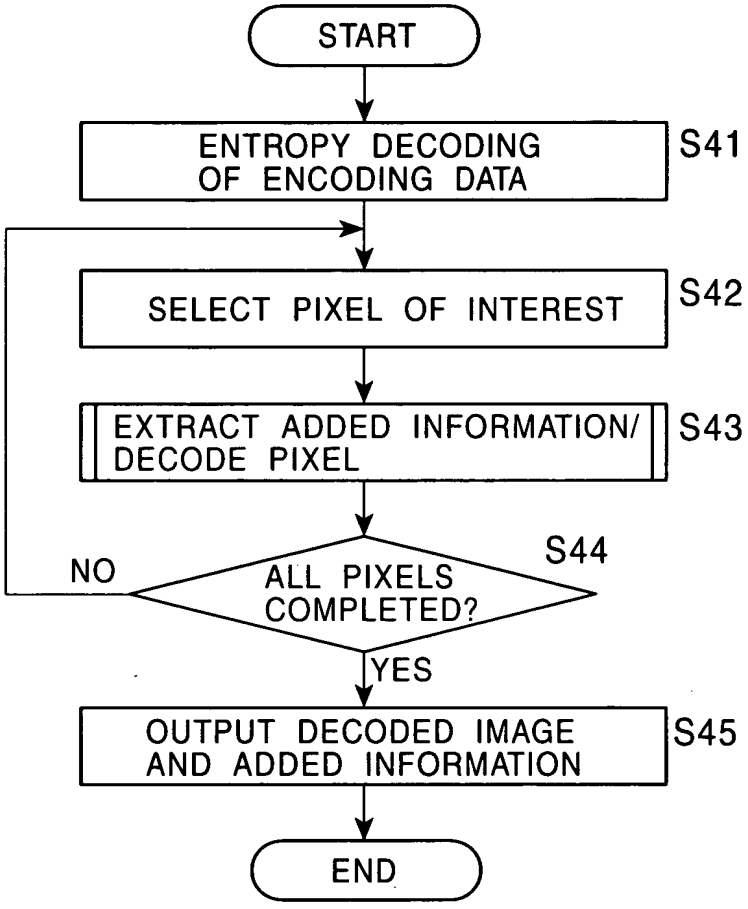

START
ENTROPY DECODING OF ENCODING DATA
S41
SELECT PIXEL OF INTEREST
S42
EXTRACT ADDED INFORMATION/ DECODE PIXEL
S43
ALL PIXELS COMPLETED?
S44
NO
YES
OUTPUT DECODED IMAGE AND ADDED INFORMATION
S45
END

FIG. 16

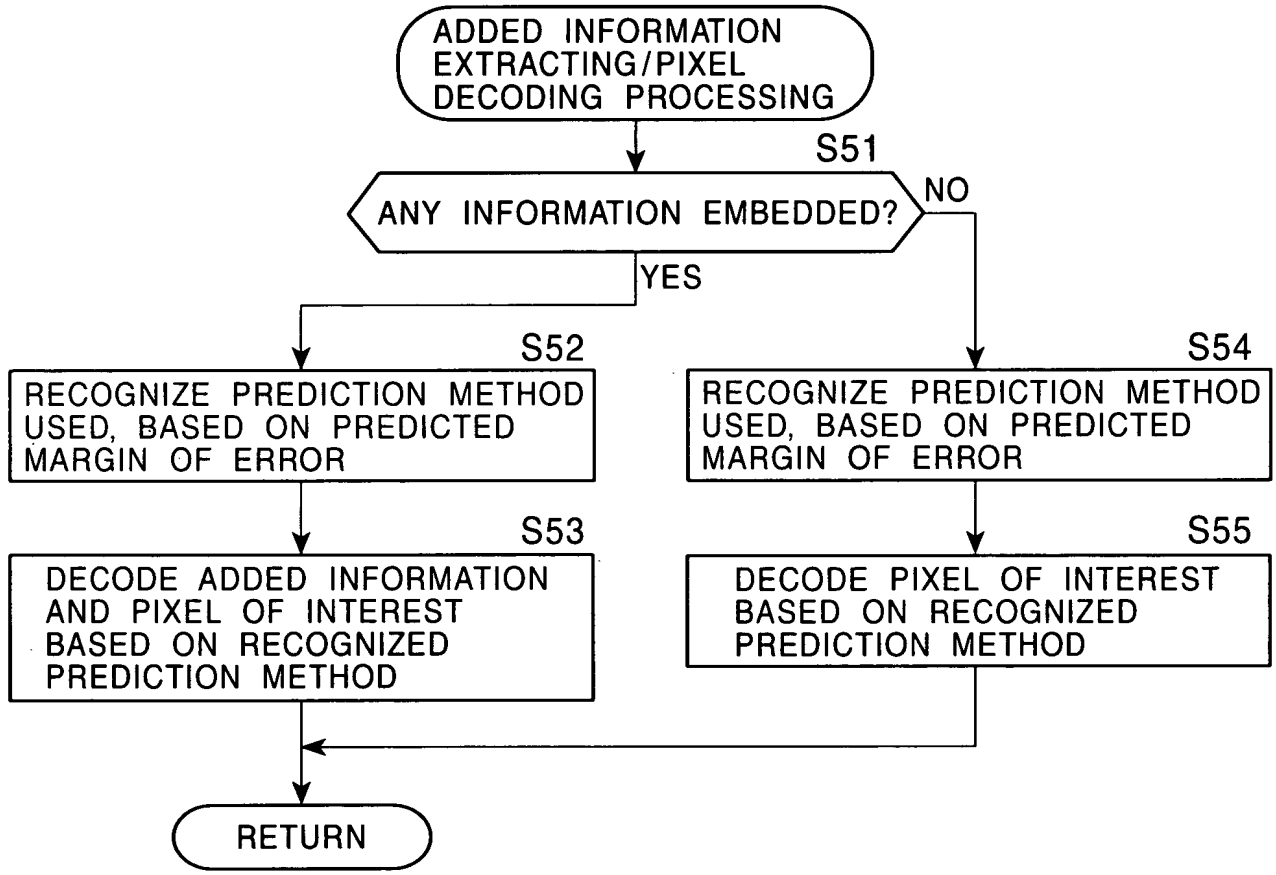

ADDED INFORMATION EXTRACTING/PIXEL DECODING PROCESSING
S51
ANY INFORMATION EMBEDDED?
NO
YES
S52
RECOGNIZE PREDICTION METHOD USED, BASED ON PREDICTED MARGIN OF ERROR
S53
DECODE ADDED INFORMATION AND PIXEL OF INTEREST BASED ON RECOGNIZED PREDICTION METHOD
S54
RECOGNIZE PREDICTION METHOD USED, BASED ON PREDICTED MARGIN OF ERROR
S55
DECODE PIXEL OF INTEREST BASED ON RECOGNIZED PREDICTION METHOD
RETURN

FIG. 17

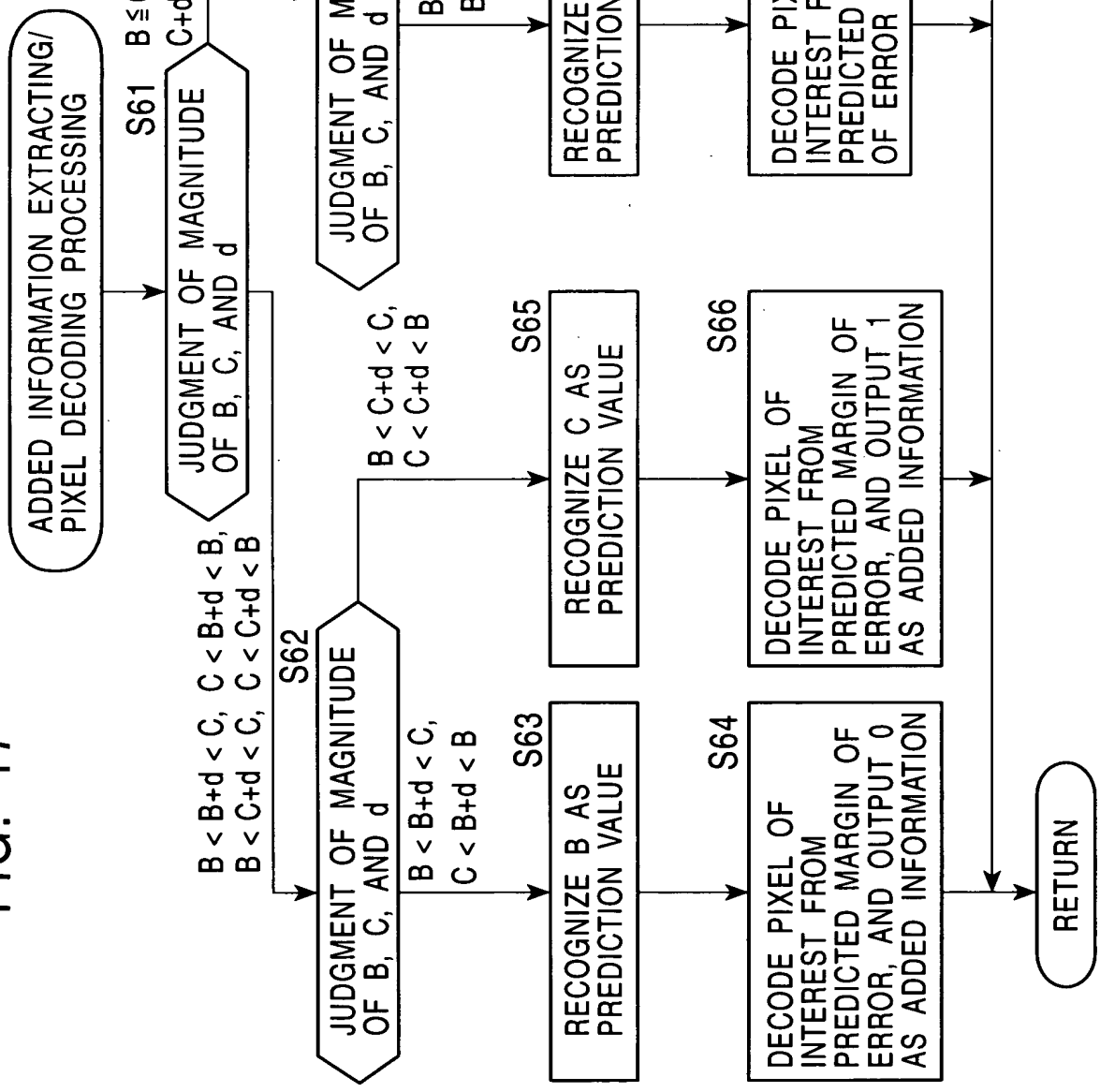

ADDED INFORMATION EXTRACTING/ PIXEL DECODING PROCESSING
S61
JUDGMENT OF MAGNITUDE OF B, C, AND d
B < B+d < C, C < B+d < B, B < C+d < C, C < C+d < B
B ≦ C ≦ B+d, B+d ≦ C < B, C+d ≦ B ≦ C, C < B ≦ C+d
S62
JUDGMENT OF MAGNITUDE OF B, C, AND d
B < B+d < C, C < B+d
S63
RECOGNIZE B AS PREDICTION VALUE
S64
DECODE PIXEL OF INTEREST FROM PREDICTED MARGIN OF ERROR, AND OUTPUT 0 AS ADDED INFORMATION
B < C+d < C, C < C+d < B
S65
RECOGNIZE C AS PREDICTION VALUE
S66
DECODE PIXEL OF INTEREST FROM PREDICTED MARGIN OF ERROR, AND OUTPUT 1 AS ADDED INFORMATION
S67
JUDGMENT OF MAGNITUDE OF B, C, AND d
B ≦ C ≦ B+d, B+d ≦ C < B
S68
RECOGNIZE B AS PREDICTION VALUE
S69
DECODE PIXEL OF INTEREST FROM PREDICTED MARGIN OF ERROR
C+d ≦ B ≦ C, C < B ≦ C+d
S70
RECOGNIZE C AS PREDICTION VALUE
S71
DECODE PIXEL OF INTEREST FROM PREDICTED MARGIN OF ERROR
RETURN

FIG. 18

| RELATION OF B, C, AND d | | JUDGMENT RESULTS OF EMBEDDED INFORMATION | ADDED INFORMATION | DECODED VALUE |
|---|---|---|---|---|
| B ≠ C | B < B+d < C OR C < B+d < B | YES | 0 | B+d |
| | B < C+d < C OR C < C+d < B | YES | 1 | C+d |
| | B < C ≦ B+d OR B+d ≦ C < B | NO | —— | B+d |
| | C+d ≦ B < C OR C < B ≦ C+d | NO | —— | C+d |
| B = C | —— | NO | —— | B+d |

# FIG. 19

| RELATION OF A, B, C, AND d | | JUDGMENT RESULTS OF EMBEDDED INFORMATION | ADDED INFORMATION | DECODED VALUE |
|---|---|---|---|---|
| $B \neq C$ | $B < B+d < C$ OR $C < B+d < B$ | YES | 0 | B+d |
| | $B < C+d < C$ OR $C < C+d < B$ | YES | 1 | C+d |
| | $B < C \leqq B+d$ OR $B+d \leqq C < B$ | NO | —— | B+d |
| | $C+d \leqq B < C$ OR $C < B \leqq C+d$ | NO | —— | C+d |
| $A \neq B = C$ | $A < A+d < B$ OR $B < A+d < A$ | YES | 0 | A+d |
| | $A < B+d < B$ OR $B < B+d < A$ | YES | 1 | B+d |
| | $A < B \leqq A+d$ OR $A+d \leqq B < A$ | NO | —— | A+d |
| | $B+d \leqq A < B$ OR $B < A \leqq B+d$ | NO | —— | B+d |
| $A = B = C$ | —— | NO | —— | A+d |

FIG. 20

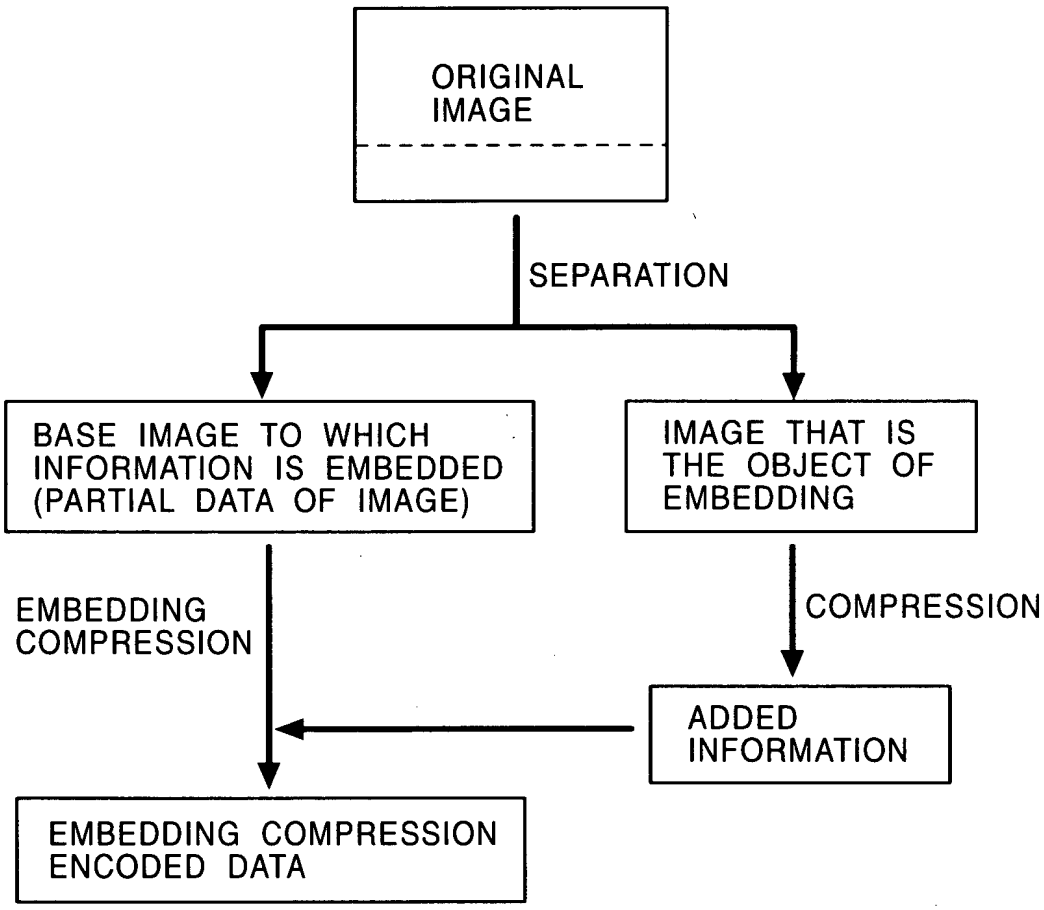

ORIGINAL IMAGE
SEPARATION
BASE IMAGE TO WHICH INFORMATION IS EMBEDDED (PARTIAL DATA OF IMAGE)
IMAGE THAT IS THE OBJECT OF EMBEDDING
EMBEDDING COMPRESSION
COMPRESSION
ADDED INFORMATION
EMBEDDING COMPRESSION ENCODED DATA

FIG. 21

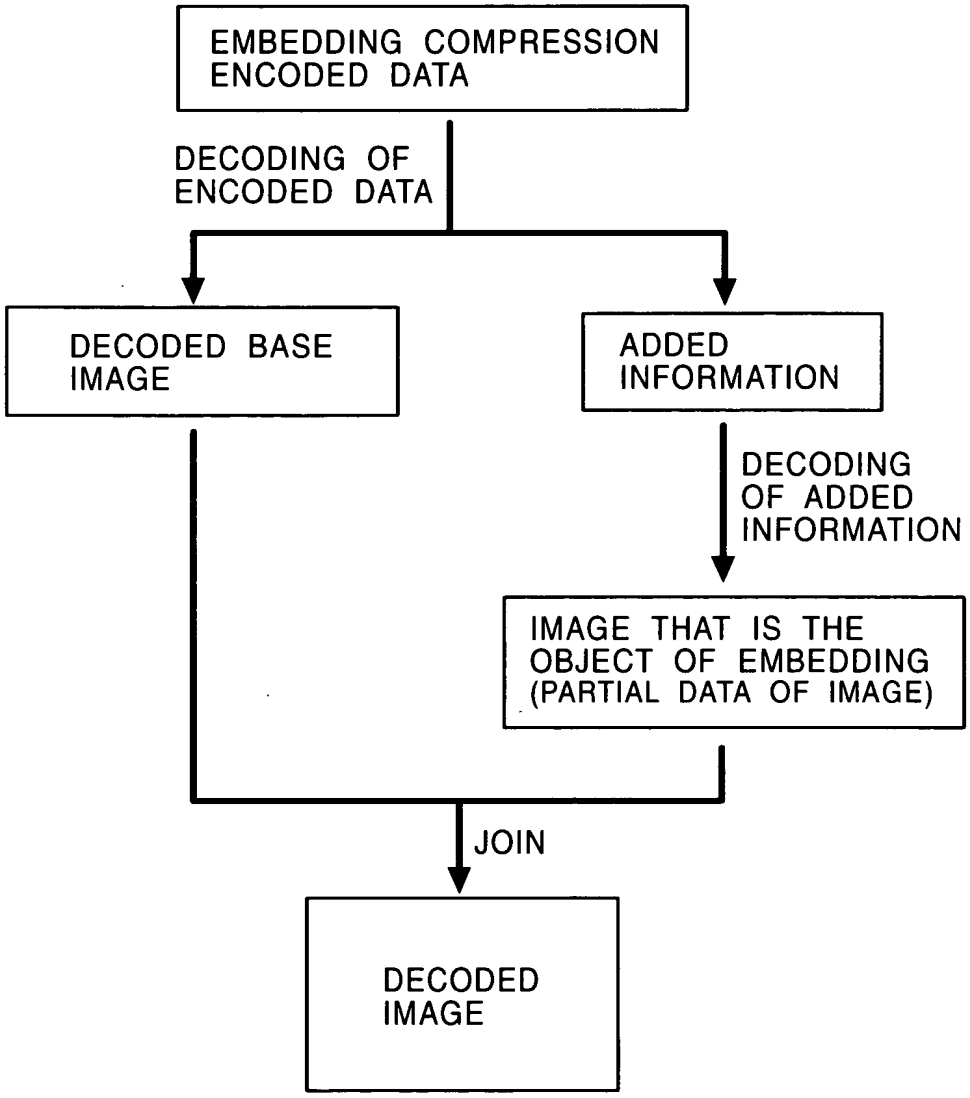

EMBEDDING COMPRESSION ENCODED DATA
DECODING OF ENCODED DATA
DECODED BASE IMAGE
ADDED INFORMATION
DECODING OF ADDED INFORMATION
IMAGE THAT IS THE OBJECT OF EMBEDDING (PARTIAL DATA OF IMAGE)
JOIN
DECODED IMAGE

FIG. 22

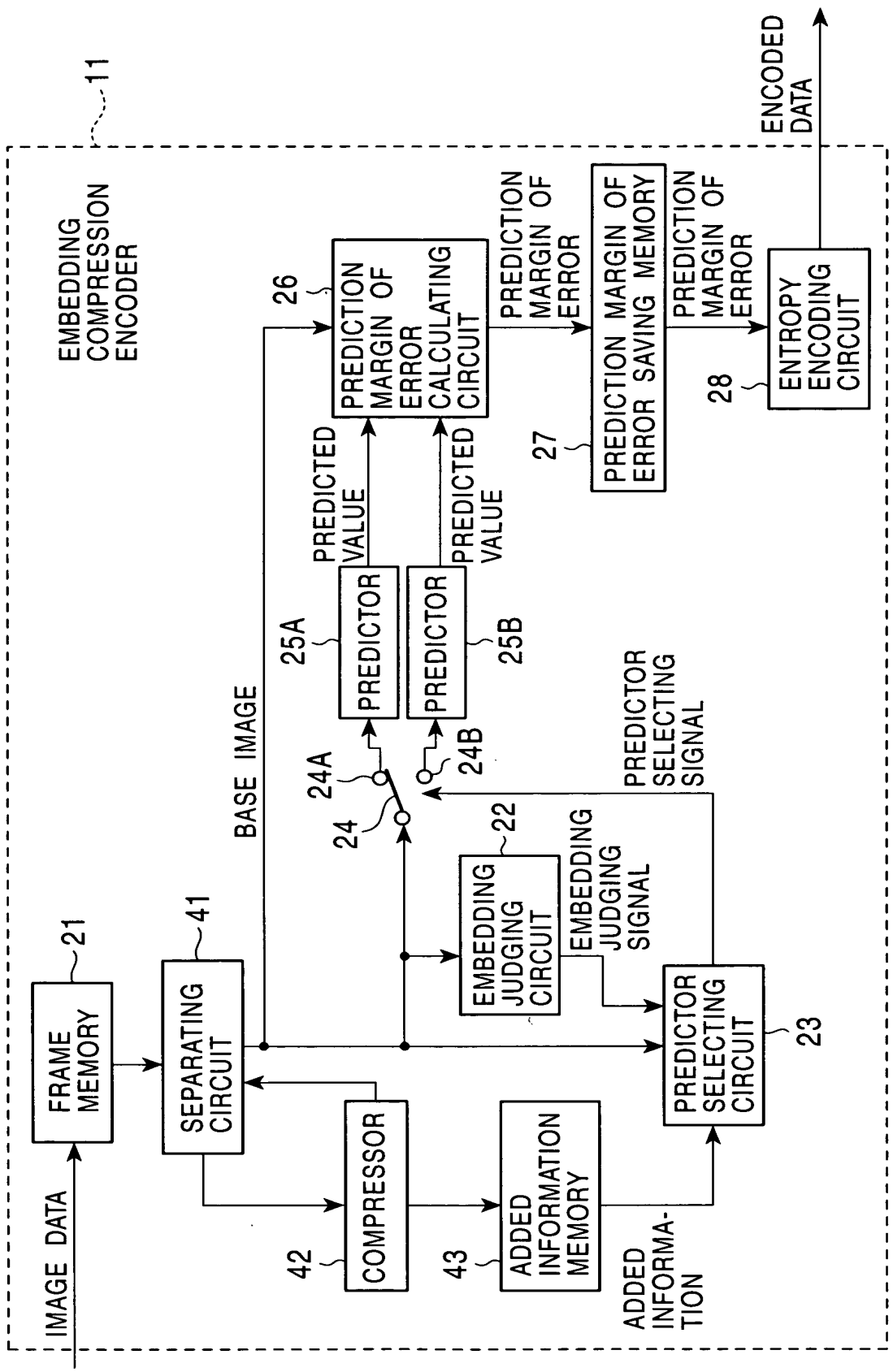

11
EMBEDDING COMPRESSION ENCODER
ENCODED DATA
IMAGE DATA
21
FRAME MEMORY
41
SEPARATING CIRCUIT
BASE IMAGE
26
PREDICTION MARGIN OF ERROR CALCULATING CIRCUIT
PREDICTION MARGIN OF ERROR
PREDICTION MARGIN OF ERROR SAVING MEMORY
27
PREDICTION MARGIN OF ERROR
28
ENTROPY ENCODING CIRCUIT
PREDICTED VALUE
PREDICTED VALUE
25A
PREDICTOR
PREDICTOR
25B
24A
24
24B
PREDICTOR SELECTING SIGNAL
22
EMBEDDING JUDGING CIRCUIT
EMBEDDING JUDGING SIGNAL
PREDICTOR SELECTING CIRCUIT
23
42
COMPRESSOR
43
ADDED INFORMATION MEMORY
ADDED INFORMATION

FIG. 23

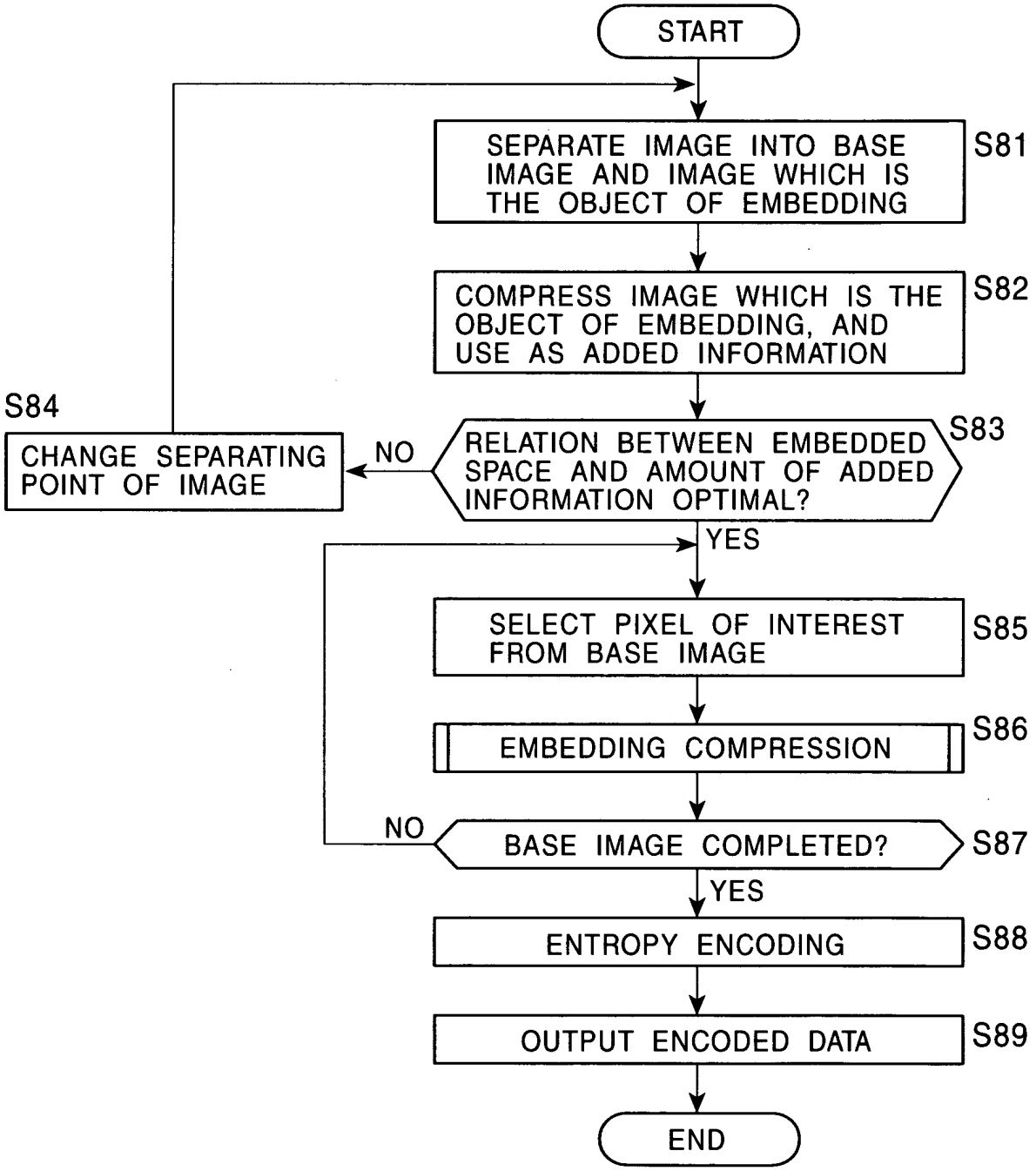

START
SEPARATE IMAGE INTO BASE IMAGE AND IMAGE WHICH IS THE OBJECT OF EMBEDDING
S81
COMPRESS IMAGE WHICH IS THE OBJECT OF EMBEDDING, AND USE AS ADDED INFORMATION
S82
RELATION BETWEEN EMBEDDED SPACE AND AMOUNT OF ADDED INFORMATION OPTIMAL?
S83
NO
CHANGE SEPARATING POINT OF IMAGE
S84
YES
SELECT PIXEL OF INTEREST FROM BASE IMAGE
S85
EMBEDDING COMPRESSION
S86
NO
BASE IMAGE COMPLETED?
S87
YES
ENTROPY ENCODING
S88
OUTPUT ENCODED DATA
S89
END

FIG. 24

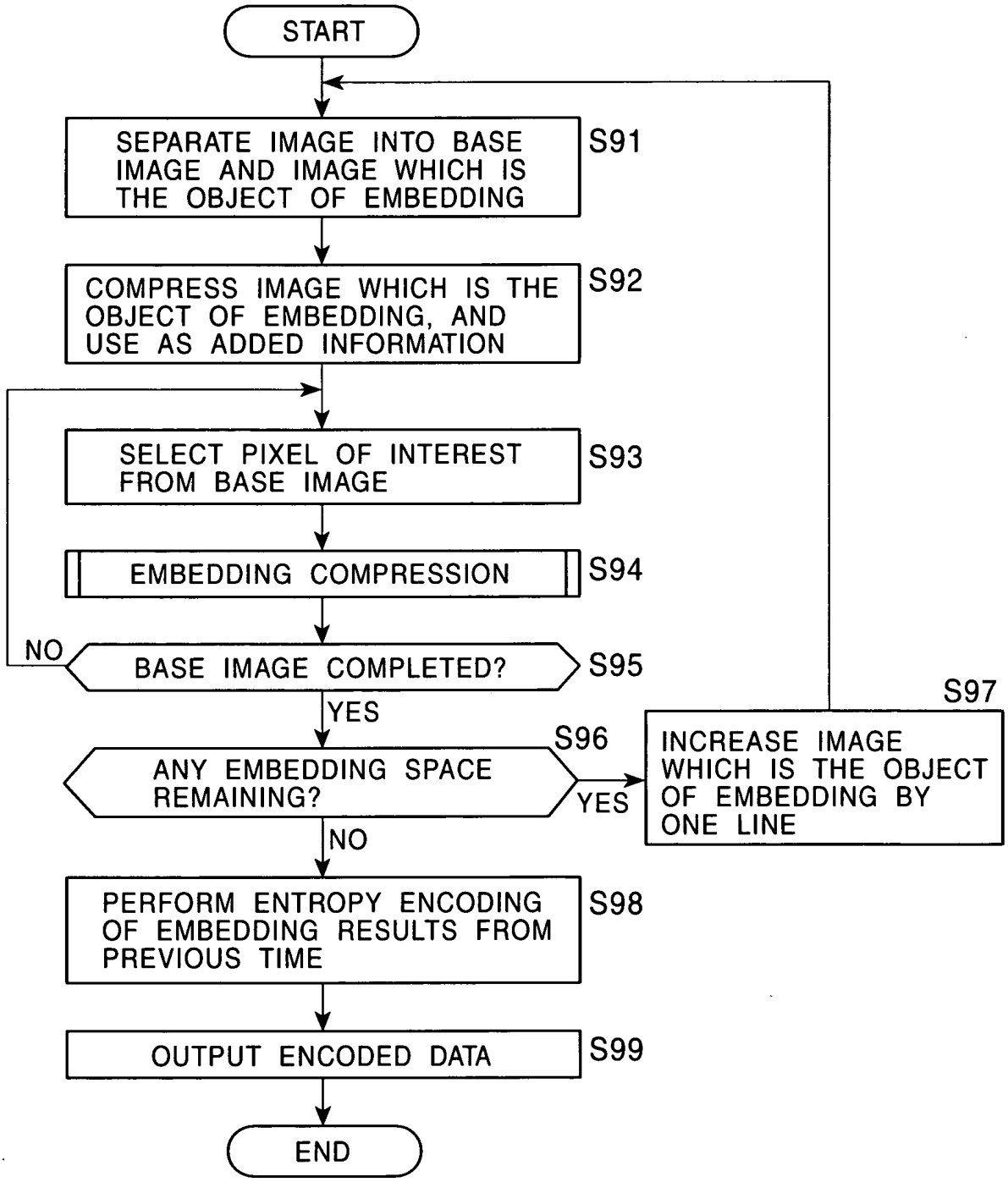

START
SEPARATE IMAGE INTO BASE IMAGE AND IMAGE WHICH IS THE OBJECT OF EMBEDDING
S91
COMPRESS IMAGE WHICH IS THE OBJECT OF EMBEDDING, AND USE AS ADDED INFORMATION
S92
SELECT PIXEL OF INTEREST FROM BASE IMAGE
S93
EMBEDDING COMPRESSION
S94
NO
BASE IMAGE COMPLETED?
S95
YES
S96
ANY EMBEDDING SPACE REMAINING?
YES
S97
INCREASE IMAGE WHICH IS THE OBJECT OF EMBEDDING BY ONE LINE
NO
PERFORM ENTROPY ENCODING OF EMBEDDING RESULTS FROM PREVIOUS TIME
S98
OUTPUT ENCODED DATA
S99
END

FIG. 25

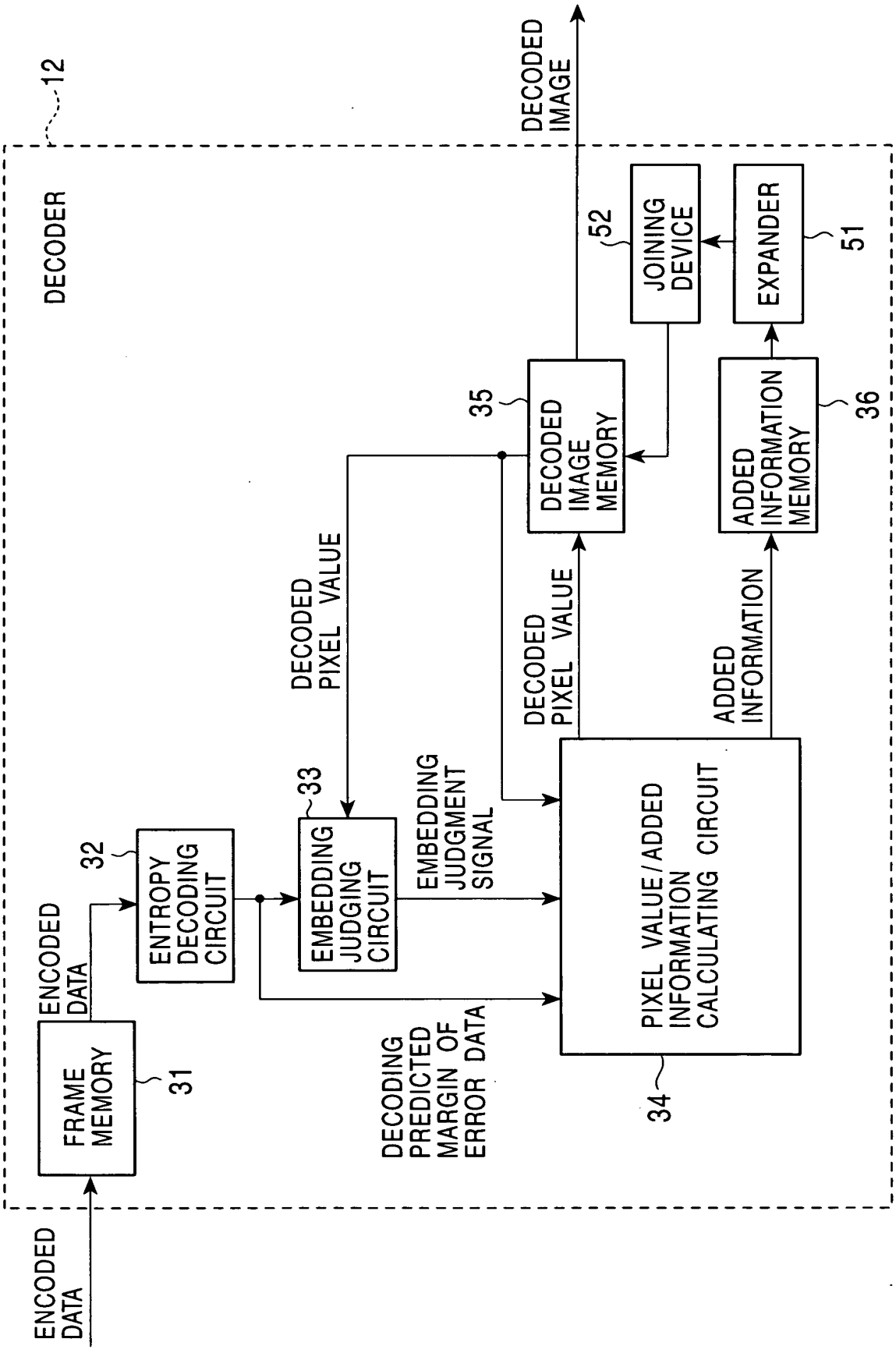

ENCODED DATA
FRAME MEMORY
31
ENCODED DATA
32
ENTROPY DECODING CIRCUIT
33
EMBEDDING JUDGING CIRCUIT
DECODED PIXEL VALUE
EMBEDDING JUDGMENT SIGNAL
DECODING PREDICTED MARGIN OF ERROR DATA
PIXEL VALUE/ADDED INFORMATION CALCULATING CIRCUIT
34
DECODED PIXEL VALUE
ADDED INFORMATION
35
DECODED IMAGE MEMORY
ADDED INFORMATION MEMORY
36
52
JOINING DEVICE
EXPANDER
51
DECODED IMAGE
DECODER
12

FIG. 26

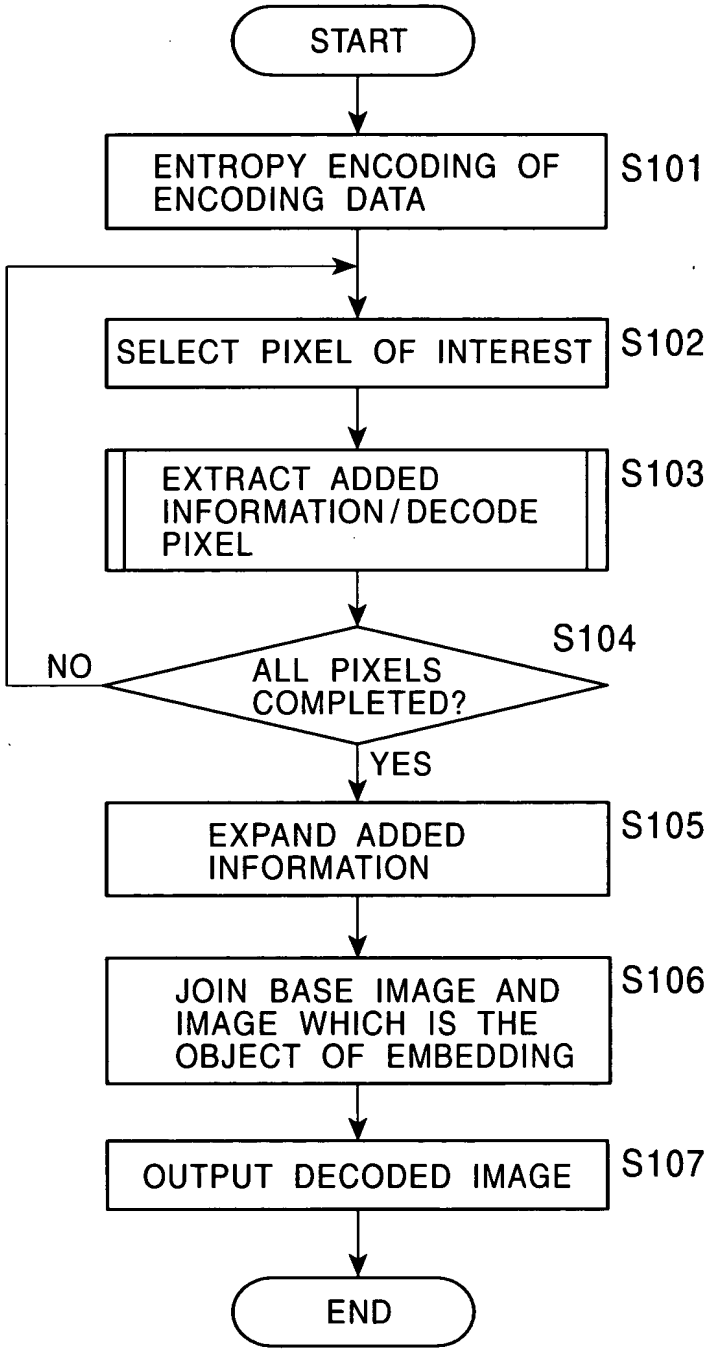

START
ENTROPY ENCODING OF ENCODING DATA
S101
SELECT PIXEL OF INTEREST
S102
EXTRACT ADDED INFORMATION / DECODE PIXEL
S103
S104
NO
ALL PIXELS COMPLETED?
YES
EXPAND ADDED INFORMATION
S105
JOIN BASE IMAGE AND IMAGE WHICH IS THE OBJECT OF EMBEDDING
S106
OUTPUT DECODED IMAGE
S107
END

FIG. 27

| COMPRESSING METHOD | IMAGE #1 | IMAGE #2 |
|---|---|---|
| PRESENT METHOD | 0.681 | 0.519 |
| CONVENTIONAL PREDICTION ENCODING | 0.691 | 0.539 |

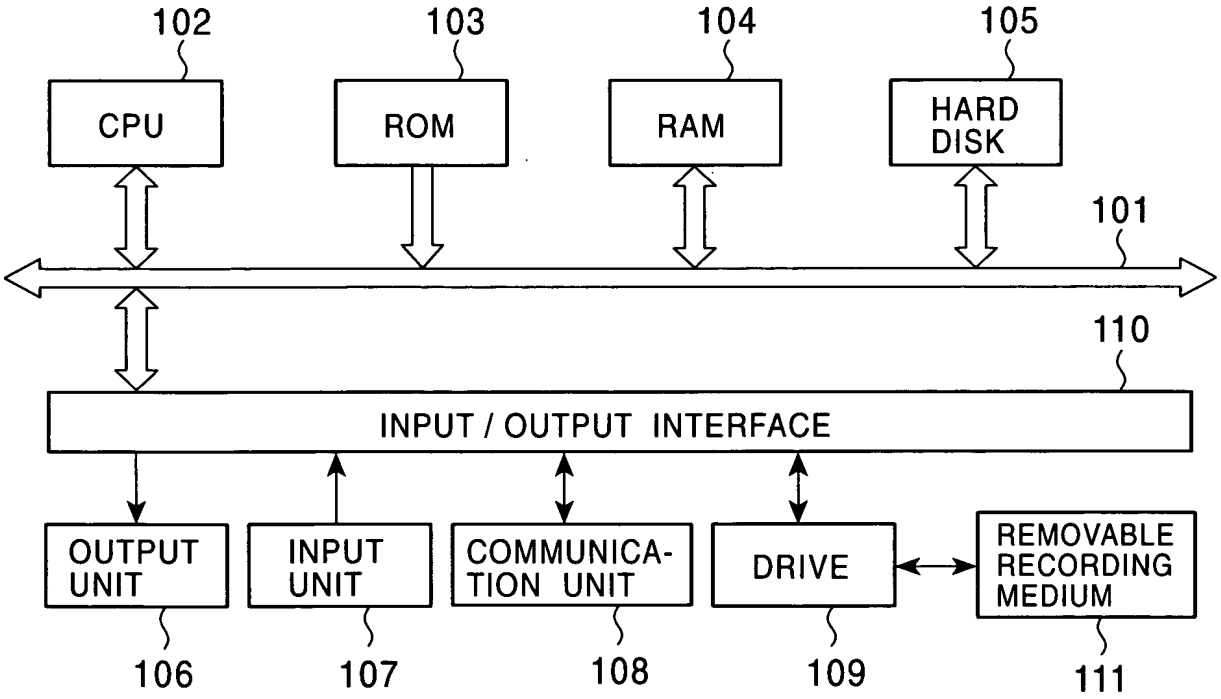



FIG. 28